3. CHEMICAL AND PHYSICAL INFORMATION

3.1 CHEMICAL IDENTITY

The chemical formula and identification numbers for plutonium are listed in Table 3-1.

3.2 PHYSICAL AND CHEMICAL PROPERTIES

Important physical and chemical properties of plutonium and its compounds are listed in Table 3-2. There are 15 known isotopes of plutonium which have atomic weights ranging from 232 to 246. Of these. only plutonium isotopes 236 to 243 are of particular biological interest either as a result of their production in nuclear processes or because of other uses (Nenot and Stather 1979). Therefore, only these isotopes are listed in the tables. The radiological properties for plutonium isotopes are presented in Table 3-3. Decay schemes for plutonium-239 and plutonium-241 are given in Figure 3-l and Figure 3-2.

Plutonium is a very reactive metal and oxidizes readily in moist air. In finely divided form, plutonium metal is pyrophoric (Taylor 1973). Plutonium exhibits five oxidation states from plutonium(II1) to plutonium(VI1). The four lower oxidation states are stable in solution and may co-exist in the same solution. Complex (coordination) compounds are formed with many of the common inorganic anions, such as plutonium nitrate ($Pu(NO_3)_4$).

A large number of plutonium compounds have been prepared in the solid state. Plutonium metal is attacked by all common gases at elevated temperatures; thus ammonia and nitrogen form nitrides, hydrogen forms hydrides, the halogens and gaseous halogen acids produce halides, carbon monoxide forms carbides, and carbon dioxide produces carbides and dioxides (Cleveland 1970). An in-depth review of the chemistry of plutonium and its compounds is given in Cleveland (1970).

TABLE 3-1. Chemical Identity of Plutonium and Selected Plutonium Compounds[a]

Property	Value					
	Plutonium	Plutonium Dioxide	Plutonium Nitride	Plutonium Hexafluoride	Plutonium Oxalate	Plutonium Tetrafluoride
Chemical name	Plutonium	Plutonium dioxide	Plutonium nitride	Plutonium hexafluoride	Plutonium oxalate	Plutonium tetrafluoride
Isotopes	Plutonium-236 Plutonium-237 Plutonium-238 Plutonium-239 Plutonium-240 Plutonium-241 Plutonium-242 Plutonium-243	No data	No data	No data	No data	No data
Trade names[b]	Plutonium metal	Oxide	Nitride	Halide	Oxalate complex	Halide
Chemical formula	Pu	PuO_2	PuN	PuF_6	$Pu(C_2O_4)_2 \cdot 6H_2O$	PuF_4
Chemical structure	No data	No data	No data	No data	No data	No data
Identification numbers:						
CAS Registry[c]	7440-07-5	No data	No data	No data	No data	No data
NIOSH RTECS	No data	No data	No data	No data	No data	No data
EPA Hazardous Waste	No data	No data	No data	No data	No data	No data
OHM/TADS	No data	No data	No data	No data	No data	No data
DOT/UN/NA/IMCO[d] Shipping	UN 2918	No data	No data	No data	No data	No data
HSDB	No data	No data	No data	No data	No data	No data
NCI	No data	No data	No data	No data	No data	No data

CAS = Chemical Abstract Service
DOT/UN/NA/IMCO = Department of Transportation/United Nations/North America/International Maritime Dangerous Goods Code
EPA = Environmental Protection Agency
HSDB = Hazardous Substance Data Base
NCI = National Cancer Institute
NIOSH = National Institute for Occupational Safety and Health
OHM/TADS = Oil and Hazardous Materials/Technical Assistance Data System
RTECS = Registry of Toxic Effects of Chemical Substances

[a]Source: Weast 1980, unless otherwise stated.
[b]Trade names were obtained from Taylor 1973.
[c]CAS Registry number obtained from Windholz 1983.
[d]DOT identification number obtained from 49 CFR 172.101 1988.

TABLE 3-2. Physical and Chemical Properties of Plutonium and Selected Plutonium Compounds[a]

Property	Value					
	Plutonium	Plutonium Dioxide	Plutonium Nitride	Plutonium Hexafluoride	Plutonium Oxalate	Plutonium Tetrafluoride
Molecular weight	242.00	274.00	256.01	355.99	526.13	317.99
Color	Silver-white	Yellowish-green	Black	Reddish-brown	Yellowish-green	Pale brown
Physical state[b]	Metal	Solid	Hard solid	Solid	Solid	Solid
Melting point, °C	639.5	2200-2400	No data	50.75	No data	No data
Boiling point, °C	3232	No data	No data	62.3	No data	No data
Density at 20°C	19.84	11.46	14.25	No data	No data	7.0
Odor	Odorless	No data	No data	No data	No data	No data
Odor threshold:						
Water	No data	No data	No data	No data	No data	No data
Air	No data	No data	No data	No data	No data	No data
Solubility:[b]						
Water at 20°C	No data	No data	Hydrolized in cold water	Decomposes in cold water	Insoluble in water	Insoluble in water
Organic solvents	No data	No data	No data	No data	No data	No data
Partition coefficients:						
Log octanol/water	No data	No data	No data	No data	No data	No data
Log Koc	No data	No data	No data	No data	No data	No data
Vapor pressure	No data	No data	No data	No data	No data	No data
Henry's law constant	No data	No data	No data	No data	No data	No data
Autoignition temperature	No data	No data	No data	No data	No data	No data
Flashpoint	No data	No data	No data	No data	No data	No data
Flammability limits	No data	No data	No data	No data	No data	No data
Valence state	+3,+4,+5,+6,+7	No data	No data	No data	No data	No data

[a]Source: Weast 1980, unless otherwise noted.
[b]The physical state for all compounds and the solubility for PuF_4 were obtained from Taylor (1973).

TABLE 3-3 Radiological Properties of Plutonium Isotopes[a]

Isotope	Half-life (years)	Decay Modes and Energy[b] (Mev)	Decay Product[c]	Specific Activity (μCi)/gm)
^{236}Pu	2.85	α, 5.75 SF, 5.722	Uranium-232	5.32×10^{8}
^{237}Pu	0.125	EC, 0.22	Uranium-233	1.21×10^{10}
^{238}Pu	87.8	α, 5.46 SF, 5.456	Uranium-234	1.71×10^{7}
^{239}Pu	24,390.0	α, 5.243	Uranium-235	6.13×10^{4}
^{240}Pu	6,537.0	α, 5.255 SF, 5.123	Uranium-236	2.28×10^{5}
^{241}Pu	15.02	ß, 0.0208	Americium-241	9.90×10^{7}
^{242}Pu	387,000.0	α, 4.89	Uranium-238	3.82×10^{3}
^{243}Pu	56,600.0	ß, 0.59	Americium-243	2.60×10^{12}

SF = Spontaneous Fission
EC = Electron Capture

[a]Source: Nenot and Stather (1979), unless otherwise stated.
[b]Spontaneous fission and electron capture energies obtained from Weast (1980).
[c]Decay product information derived from Walker et al. (1977).

Am							
Pu	239 Pu 24,065 yrs						
Np	↓						
U	235 U 7.038E8 yrs						
Pa	↓	231 Pa 3.276E4 yrs					
Th	231 Th 25.52 hrs	↓	227 Th 18.718 days				
Ac		227 Ac 21.773 yrs	↓				
Ra			223 Ra 11.43 days				
Fr			↓				
Rn			219 Rn 3.96 s				
At			↓				
Po			215 Po 0.001780 s				
Bi			↓	211 Bi 2.14 min			
Pb			211 Pb 36.1 min	↓	207 Pb stable		
Tl				207 Tl 4.77 min			

↓ alpha decay

↗ beta decay

Figure 3-1. Plutonium-239 Decay Series

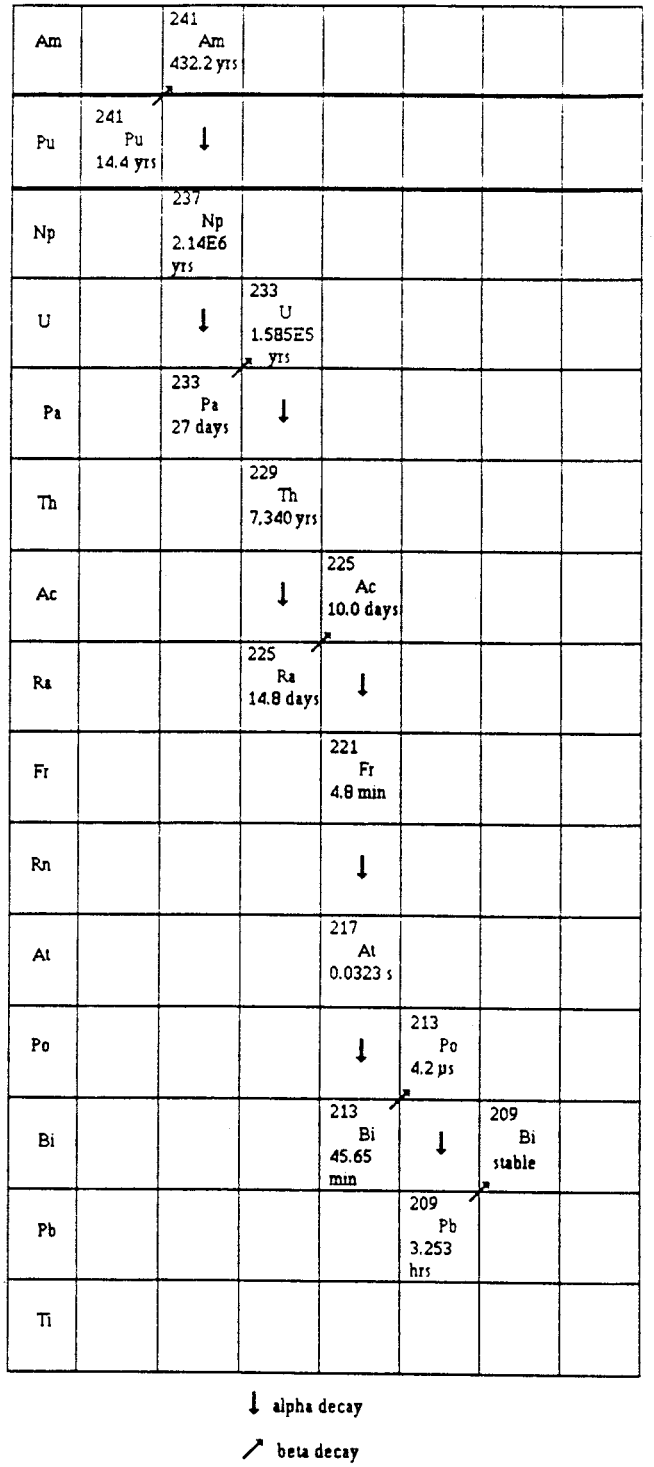

Figure 3-2. Plutonium-241 Decay Series